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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Measuring FeO variation using astronomical spectroscopic observations" *by* Stefanie Unterguggenberger et al.

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Response to interactive comment by C. von Savigny

General comments:

This is an interesting manuscript dealing with ground-based observations of two terrestrial nightglow emission features, i.e. the FeO orange bands and the well-known Na D-lines. The spectral observations were carried out with the X-shooter spectrograph at the Very Large Telescope in Chile. The FeO and Na emissions show similar diurnal and seasonal variations. Comparisons with WACCM model simulations allow empirical estimation of the (effective) quantum yields for the two emissions, which are not well known. The paper is of interest to the aeronomy community and is in general very well written. A few paragraphs and sentences are difficult to follow (see specific comments

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Discussion paper

below). I don't have any major objections against the publication of this manuscript and recommend publication subject to minor revisions. I ask the authors to consider the specific comments listed below.

Specific comments:

Page 3, line 20: "as A pseudo-continuum"
The phrase was changed as proposed.

Page 7, line 9: "We tested our results with respect to the data distribution over the year by introducing equally spaced bins"
I don't fully understand what you mean here? How many bins were used? Howwide/long were they? Do they have to be equally spaced?
The bins were equally spaced over the year with each bin having a width of 2 weeks, which left us with 26 data points over the year. For clarification the sentence was edited as follows: 'We tested our results with respect to the data distribution over the year by introducing equally spaced bins, spanning a fortnight.'

Figure 2: I have some questions about this Figure: (a) Is the ordinate label / unit correct? The plot shows the spectral intensity, so the unit should be R / (wavelength unit), e.g. R/nm, right? This applies to both panels. (b) You write that the cyan line in the top panel corresponds to the FeO continuum, while the black line shows the raw spectrum. What is the origin of the offset between the two lines? Is it possible that the cyan line is offset by 100 R for better visibility? If yes, this is not mentioned, as far as I can tell.
Yes, the label on the ordinate was wrong and has been corrected.
The offset between the black and the cyan spectrum results from the data reduction. With the help of the sky model we corrected the night-sky spectrum for zodiacal light, scattered star- and moonlight. This correction causes the offset between the two

spectra. This information was added to the text.

Page 9, line 19: Evans et al. found a NiO/FeO ratio of 0.05 to 0.3 and Gattinger et al. a ratio of 2.3. Is the large difference between these results understood.
There was a typo with the second reference. Both measurements (OSIRIS and the space shuttle) were mentioned in Evans et al (2011). This was corrected.
In the paper Evans 11 no answer was given to why they found these big discrepancies in their measurements. This information was added to the text: 'These differences were not discussed in detail in Evans et. al. (2011).'

Page 9, line 26/27: "we find a maximum contribution of 31% to the mean peak" I suggest adding "of the FeO emission" here (this is what you mean, right?)
Indeed, in single spectra we could find a possible contribution of the main peak by NiO that amount to almost 1/3 of the total main peak intensity. This information was added to the text as follows: 'Using this peak to scale the laboratory NiO spectrum accordingly we find a maximum contribution to the FeO main peak intensity by NiO of 31%... '

Page 10, line 2: "Scaling the main peak emission from Gattinger et al. (2011) to the whole spectrum we obtain a value of 3.9%"
I think some pieces of information are missing here. What "value" do you mean? Even after reading the sentence several times, I'm not sure I interpret it correctly. Please clarify.
Due to other airglow contamination like different OH bands, NiO and NO+O it is difficult to measure the FeO spectrum. The most reliable part is the main peak. Since we wanted to see how much of the total FeO intensity is contained within the main peak, we took the the theoretical FeO spectrum from Gattinger et al. (2011) and scaled it to the total FeO flux. Hence, the 3.9 % refer to the contribution of the main peak to the total FeO spectrum. '... FeO pseudo-continuum...' was added for clarification.

Page 10, line 10: "where the main peak amounts to 3.3 $\pm$0.8%" 3.3% of what? This is related to the previous point. Please clarify.
The Gattinger spectrum spans a wavelength range from 0.5 to 0.72 micron. The main peak is only a small part of the total emission. Hence, if one is interested in the total intensity of the FeO emission, it is necessary to to scale the main peak emission to the total emission of FeO. For a better comparison between the spectrum obtained by Gattinger and our reconstructed spectrum we compared the contribution of the main peak to the total pseudo-contiuum. We add '...of the total FeO emission ranging from 0.50 to 0.72 micron...' as clarification to the text.

Page 11, line 6: "In general, the Na and FeO emission show similar diurnal variation within their combined errors, i.e. Figs. 4a, c, and d." This statement is also true for 4b, and even more so than for, e.g. 4d or 4a. Next sentence: "The intensities of FeO and Na decline at the beginning of the night and rise towards sunrise"
This is not true for 4b. I think you intend to only mean panels a, c d here, right? But this is not explicitly stated by this or the previous sentence (the phrase "i.e. Figs. 4a, c and d" does not imply that).
Thank you very much for finding this. We corrected for the errors.

Page 11, last line: "The best fit approach ($\chi 2_{min}$) relies on the grid size and does not provide uncertainties"
After reading the entire paragraph I understand what you mean, but there are different "best-fit" approaches. You create arrays with possible fit parameters and then determine chiËĘ2 for each set of possible combinations. One may also use – and I think this is generally done – numerical routines to find the optimum fit values in a least-squares sense. I suggest mentioning at the beginning that you don't use a numerical scheme to minimize $\chi 2$. Otherwise, the reader has difficulties understanding what you mean by "relies on the grid size" – this is not correct for the numerical methods. Also the

numerical methods will generally provide uncertainty estimates.
A clarification was added to the text as follows:
'Since the best-fit approach ($\chi 2_{min}$) is not done with a numerical scheme but makes use of a parameter grid, it relies on the grid size and does not provide uncertainties.'

Page 12, line 8: "parmeter" -> "parameter"
The typo was corrected.

Page 12, line 22: "stronger .. amplitude" -> "larger .. amplitude" ?
The word was corrected.

Page 13, line 8: "at the end of May"
Isn't it rather the end of April? We checked the data again and the maximum is on DOY 116, which corresponds to the end of April. The correction was applied to the text.

Page 14, line 23: "by convolving" Is this really a convolution in the mathematical sense? This may well be the case, but I'm not entirely sure.
Convolved was changed into 'by combining in quadrature'.

Page 15, line 3: "convolving"
Same as above point.
Convolved was changed into 'by combining in quadrature'.

Page 15, line 9: "Fig, 9" -> "Fig. 9"
The typo was corrected.

Page 15, last sentence: I think it's also worth mentioning that Clemesha et al. (1995) performed a minimization of the differences between the observed Na emission rates and model simulations, which resulted in a value of f = 0.093. Also, in our

recent manuscript (von Savigny et al., First mesopause Na retrievals from satellite Na D-line nightglow observations, Geophys. Res. Lett., revised, 2016) we find an optimum value of f = 0.09, when comparing Na retrievals from SCIAMACHY Na nightglow observations with independent satellite observations (SCIAMACHY dayglow and GOMOS stellar occultation). I should point out that we varied f in steps of 0.01 to find the optimum value – an approach that can be refined. In any case, I find it encouraging that your results on the value of the effective quantum yield are in good overall agreement with the von Savigny et al. (2016) value and with Clemesha et al. (1995).
The additional information was added at the end of the result section.

Fig. 4, caption, line 1: I Suggest replacing "with respect to season" by "for different seasons". Same line: space in ".The" missing.
The space was added and the phrase changed to the suggested version.

Figure 5: The symbols (squares) are hardly visible in the printout. Please increase the symbol size.
The plot was edited.

Page 16, line 2: "airglow emissionS" ?
The typo was corrected.

Page 16, line 23: "None of the seasons showS"
The typo was corrected.

Page 23, table caption, line 2: "the relative value of A1 .."
Suggest adding "in percent" to read "the relative value (in percent) .."
Thank you for the suggestion, it was put into the table caption as 'in per cent' (British English).

Reference list: the reference list contains a fair number of typos and inconsistencies. I probably didn't catch all of them. Please check the list again carefully. A general issue: periods are missing at the end of all references. In addition, the spacing between initials is not consistent between the references.
We went through the references and corrected for mistakes and inconsistencies.

Page 22, line 9: von Savigny (2012) is not cited in the manuscript, as far as can tell (But I'm certainly happy if you cite it ..)
Sorry for that mistake. This citation was from an older version which still included OH measurements. However, your recent letter is now a part of the discussion section.

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